International Journal of Exploring Emerging Trends in Engineering (IJEETE)
Vol. 03, Issue 02, Mar-Apr, 2016 Pg. 149-154 WWW.IJEETE.COM

Spatial Information based Deployment Optimization Framework in Wireless Sensor Networks

Meghram Mokta[1], Mahendra Tyagi[2]
Department of Electronics and communication engineering
L. R. I. E. T. Solan (HP), India
[1]mokta.megh@gmail.com, [2]mahendra.tyagi9@gmail.com

Abstract- *As there are many applications of geosensor networks, these are widely used and attract many researchers. Geosensor networks are used in real world applications for object tracking, environmental monitoring and controlling events. These networks consist of set of sensor nodes placed in different locations. To monitor an environmental area a very basic issue that arise is the optimization of deployment. In this there is a problem in estimation of its spatial coverage. Coverage is the major issue, because if there are certain obstacles in the network which increase the deployment complexity and increases holes and uncovered area. These coverage holes should be detected and minimized or removed completely using coverage optimization process. Many researchers have been proposed optimization approaches. Some of these approaches use Vornoi diagram and Delaunay triangulation to identify the coverage holes in the network and optimize the sensor deployment in the area under consideration. But many of these methods reduces the performance of the network and also the quality of data. This paper gives an optimization framework by integrating spatial information while making the deployment. The approach is completely based on Vornoi approach including the spatial coverage estimation process. Finally the results have been presented with respect to performance of the network.*

Keywords: *Geosensor networks; Coverage problem; Voronoi diagram; Deployment;*

1. Introduction

In today's world electromechanical and communication systems give a rise to development of low cost, small size sensor nodes. These sensing devices are used to form wireless networks and collect information from the area under consideration like temperature, humidity, pressure, traffic, target detection etc. The collected information then will be sent to the powerful center called as base station or processing center. Base station then analyze this gathered information and try to find out some conclusions. Sensor network deployment is very useful to cover the area of interest rather than using a single node and moving it throughout the same area. Sensor nodes can be deployed randomly or manually and also the gap between the nodes can be fixed of variable according to the application requirements. The density of sensor nodes totally depends on the data quality requirements of the applications of WSN.

There are certain limitations of sensor nodes which may result in the degradation of the performance of the network and data quality. These limitations may be sensing range, energy (battery power), low storage capacity and limited computation capabilities. Many researchers have addressed these limitations in recent years from various disciplines in order to design and deploy more efficient sensor networks [11].

Placement or deployment of sensor nodes is the biggest issue in wireless sensor networks that actually affects the coverage and connectivity between the sensor nodes in the network. Sensor nodes use sensing module to gather information from surrounding area of interest. Every sensor node can be considered as the data collector from area of interest and also as a relay node which helps to transmit data toward the base station. The data sensed can be about the environmental phenomenon or some chemical or physical phenomenon. So there can be obstacles and other factors which can affect the performance of the sensor network and may create some coverage holes in the area under

consideration. Connectivity in the network towards the base station is also an important factor because the sensed data must be transferred for further processing.

Many approaches has been studied and proposed to optimize the coverage and connectivity in WSNs. Some approaches uses Vornoi diagram and Delaunay triangulation to identify coverage holes. These techniques do the optimal placement of the sensor nodes in the area of consideration and try to cover the coverage holes. However many of the methods proposed reduce the quality of optimization and spatial coverage. In this paper a new sensor network deployment method has been proposed by integrating the spatial information in the optimization method based on Vornoi approach.

The remainder of this paper is as follows. Section 2 presents a state of the art on the deployment methods in sensor geosensor networks. Section 3, describes the problem statement of the deployment in sensor networks. Section 4 proposes a new sensor deployment framework by integrating spatial information in the optimization process based on Voronoi diagram. In this section the results of the experimentations based on the proposed approach are also presented. Finally, section 5 discusses and concludes the paper and proposes future work.

2. Related Work

Wireless sensor networks remarked as the most useful and most important technology for the century in 1999 by Business Week [21]. Sensor networks are the networks of small, low cost, low power nodes which are able to collect information from the surroundings and transfer this information towards the processing center. There are wireless communication links between nodes base on radio technology. Previously, sensor networks consisted of small number of sensor nodes that were usually wired to a central processing station. However, nowadays, the focus is more on wireless, distributed, sensing nodes [22][17][20]. The characterization of the sensor node can be its sensing range, storage space, the power source (battery) and also its communication and computation capabilities. Many times the range of the sensor node is very small and can cover very small area. That's why these small sensor nodes should be used in groups in the form of a network so that a large area must be covered and a big task can be accomplished. Each sensor node of group can collect data from the environment, apply local processing, communicate it to other sensors and perform aggregations on the observed information [15].

Wireless sensor networks can also referred to as Geosensor networks as they are intensively used to acquire spatial information [11]. Hereafter, we will use both of the terms "sensors" and "geosensors" interchangeably. Geosensors can be deployed on the ground, in the air, under water, on bodies, in vehicles, and inside buildings.

There are many applications of sensor networks including the environmental, target detection, traffic monitoring, border security, etc. Wireless sensor networks built a smart environment and collect the information quickly and easily. Sensor networks are very useful in traffic monitoring, the sensors used in traffic monitoring may be under the ground or installed overhead to control the traffic lights. Furthermore, video cameras are frequently used to monitor road segments with heavy traffic, with the video sent to human operators at central locations [6]. WSNs can be used in buildings for security purpose like fire security or intruder security. Networks of video, acoustic, and other sensors provide early detection of possible threats [16]. Most of the commercial industries have been interested in sensor networks because of its high effectiveness and low cost. Monitoring machine "health" through determination of vibration or wear and lubrication levels, and the insertion of sensors into regions inaccessible by humans, are just two examples of industrial applications of sensors [6]. A broad classification of geosensor network applications is monitoring continuous phenomena, detecting real time events and tracking objects [11][17][20]. The wireless sensor network technology is mostly used for detecting and monitoring time-limited events (e.g., earthquake tremors), instead of continuous sampling in remote

areas due to the battery constraints of geosensor platforms [11].

3. Problem Definition

A voronoi based method for sensor node placement optimization has been proposed in this paper which is being used to establish a realistic sensor network. The approach proposed has been associated with digital terrain and surface models. Optimization process is combined with Geographical Information System (GIS) for integrating spatial information. Furthermore, the utilities and abilities obtainable in GIS assist more facilities in sensor network deployment. The examples of GIS operations that can be used in this regard are Visibility, line of sight and viewshed analysis. At the end the sensor nodes has been deployed based on the vornoi diagram and the topology of the sensor network and its dynamics has been considered. The dynamics considered are based on the smart antennas. The smart antennas are used to optimize the connectivity in the network and restrict the routing algorithm to waste the bandwidth. Newly proposed approach emphases on defining and implementing a framework incorporating the spatial and environmental information for optimal placement of sensor nodes based on the Voronoi diagram and deployment optimization method.

4. Proposed Deployment Framework

The proposed framework consists of two major modules: a spatial knowledgebase (GIS) and a simulation engine, based on Voronoi diagram (Figure 1). GIS has been used to implement the spatial knowledgebase in which the different environmental factors are arranged in different layers, like man-made and natural hurdles. During the sensor nodes' placement process a network coverage is calculated in each step. Another layer contains the position information of the sensor nodes in the network. Another layer i.e. the coverage layer has been considered to be varying according to the environmental information and sensor node positions. The database consist of the various spatial environment attributes which are defined in different layers. Different metric and topologic operations are then exported based on the analyses that are carried out here throughput, success rate etc.

All environmental and network parameters that made the GIS database are integrated to spatial knowledgebase that is used to extract the deployment rules and actions. Then, the knowledgebase is applied to a reasoning module for sensor network deployment. This module consists of the calculated deployment rules and facts as well as a local optimization algorithm based on Voronoi diagram. This module also generates commands to make the sensor movement inside the network to optimize the coverage level. The optimization tries to place the sensor nodes based on the extracted rules.

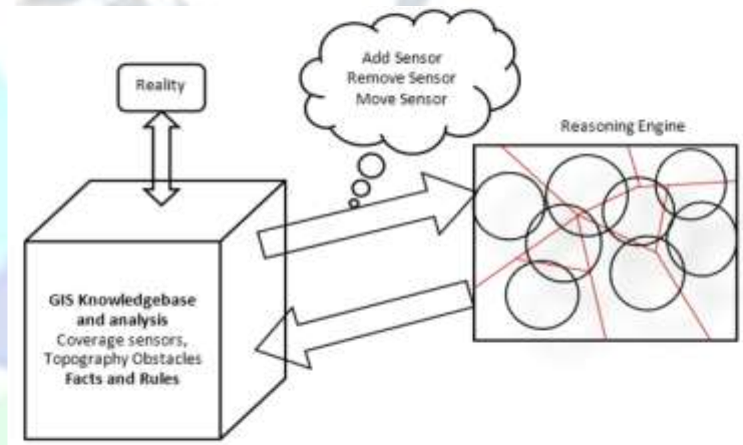

Figure 1 Proposed Deployment Framework

4.1 Implementation of the proposed Approach

For the purpose of analysis and comparison of proposed framework the simulation has been done in MATLAB. Simulation uses the environment provided by the MATLAB to simulate the computer networks and other networks. MATLAB provide a good tool to design a network of sensor nodes and also to define a sensor node and its characteristics. The designer or researcher can define the properties of the sensor node as well as the wireless sensor networks.

This section will discuss the results which are obtained by running the simulation program using different conditions in the network. The results depict the area covered by different number of nodes in the network.

The simulation results have been compared with the results of random deployment and CMA-ES. Table 5.1 shows the parameter setting of the network. The simulation has been done with the help of these settings on the network size of 50, 100, 200 nodes respectively; 3000 rounds of simulation were processed.

Table 1 Simulation Parameters

Simulation Parameter	Value
Area	100 x100 m
Number of Nodes	50, 100, 200
Initial Energy of Each node	0.5 Joule
Electronic Energy (E_{elec})	50 nJ (50*0.000000001 Joule)
Amplification Energy (E_{amp})	100 pJ (10*0.000000000001 Joule)
Packet Size	50 bits
Number of Rounds	3500

4.2 ***Random Deployment approach vs Proposed Framework***

Before applying the proposed framework for deployment the basic random deployment technique has been tested using 50, 100, and 200 nodes respectively. It can be seen from the figure 2 (for 200 nodes) that when a random deployment has been made sensor nodes are not able to cover the whole area, under consideration. When we plot Voronoi cells, each sensor cannot be able to cover the entire Voronoi cell and also there are too many sensors in one Voronoi cell. So, for the purpose of good output each Voronoi cell can be treated as sensing buffer and also as the critical area. Hence, each Voronoi cell should be covered by one sensor only, which will definitely ensure the maximum coverage of the application area.

The proposed framework try to solve this problem of coverage through the GIS knowledgebase. It extract the rules for deployment based on the information provided in the GIS knowledgebase. Also the smart antenna does its' work sensibly, and direct all the data toward the base station and do not waste bandwidth in broadcasting data. Figure 3 shows the output after applying the proposed framework for deployment of wireless sensor networks. It can be depicted from the figure that each sensor node has been deployed in its sensing buffer area and cover its own Voronoi cell. Although we can see there are some dense Voronoi cells, these dense cells are based on the knowledge of critical regions in the area where the data requirements are critical. Hence, the deployment of nodes has been optimized.

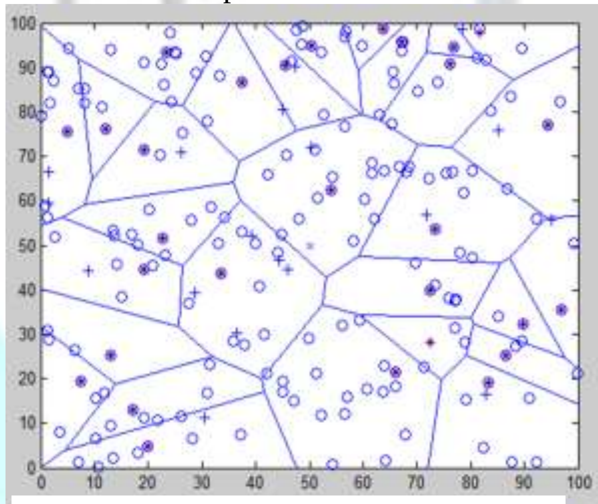

Figure 2 Initial Random Deployment

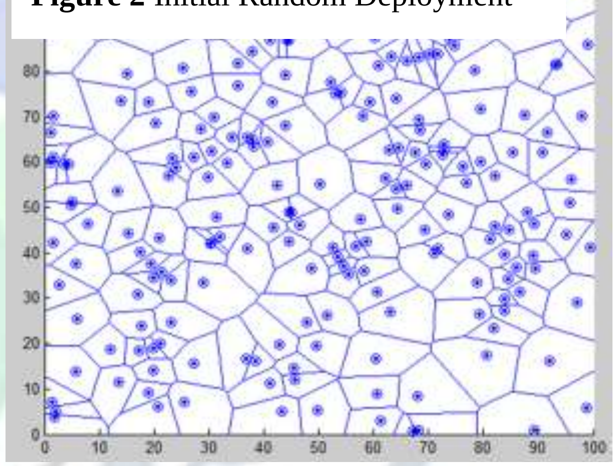

Figure 3 Sensor's positions and their related sensing buffer and Voronoi cells after applying proposed framework

4.3 Coverage Percentage (Proposed vs CMA-ES)

Figure 4 below show the coverage percentage in each round of simulation for the proposed and CMA-ES coverage optimization frameworks.

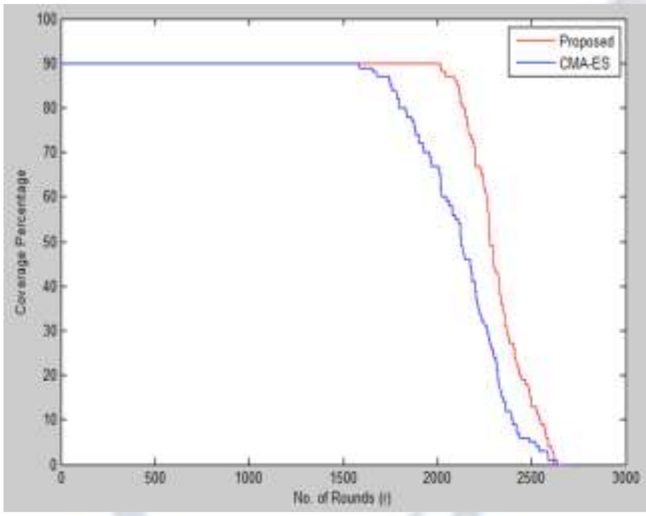

Figure 4 Coverage Percentage (Proposed vs CMA-ES)

It can be depicted from the graph that both the algorithms are starting from a coverage of 90% area. Any real time algorithm cannot give 100% coverage, but if we keep on increasing number of nodes the coverage will gets better as seen before for the cases of 50, 100 and 200 nodes. The graph is only for 200 nodes. The proposed algorithm works better than CMA-ES to retain the coverage high even after failure of some nodes. When all the nodes gets failed, the coverage will be zero for both approaches, as seen below in graph.

5. Discussion and Conclusion

The paper has presented the coverage problem in wireless sensor networks. In this paper first the existing coverage problem has been discussed and also some of the existing deployment optimization techniques have been discussed. As pointed out in most of the research works do not consider the environmental characteristics. Most of the algorithms oversimplify the coverage problem. Spatial information must be considered in sensor networks if there is a need of spatial distribution of the sensor nodes. The coverage determination algorithms try to distribute the sensors in the field so that the maximum coverage is obtained.

Voronoi diagram approach is well known as approach for adaption, abstraction and modeling of sensor networks and spatial data structures. This is also used frequently in WSNs. However, their application is still limited when it comes to the determination and optimization of spatial coverage of more complex sensor networks.

A new approach has been presented in this paper to overcome the limitations of existing approaches. It is a Voronoi based approach considering the spatial information in sensor networks deployment and coverage optimization. The proposed method of deployment has been implemented in MATLAB and performance has been checked. Throughput, success rate, packet delivery ratio has been plotted after applying the proposed deployment method has been checked and compared to the normal deployment scheme. As presented in the results, we have observed a considerable improvement in the spatial coverage of the sensor networks. In future the proposed method has been tested for some application of sensor networks and a test-bed implementation can also be good for judgment of its performance.

References

[1] Ahmed, N., Kanhere, S. & Jha, S., 2005. The holes problem in wireless sensor networks: a survey. ACM SIGMOBILE Mobile Computing and Communication Review, 1(2), pp.1–14.

[2] Argany, M. et al., 2011. A GIS based wireless sensor network coverage estimation and optimization: a voronoi approach. Transaction on Computational Science XIV, 6970, pp.151–172.

[3] Argany, M., Mostafavi, M.A. & Karimipour, F., 2010. Voronoi-Based Approaches for Geosensor Networks Coverage Determination and Optimisation: A Survey. In 2010 International Symposium on Voronoi Diagrams in Science and Engineering. IEEE, pp. 115–123.

[4] Brown, P., Bovey, J. & Chen, X., 1997. Context-aware applications: from the laboratory to the marketplace. Personal Communications, (October), pp.58–64.

[5] Cardei, M. & Wu, J., 2004. Coverage in wireless sensor networks. Handbook of Sensor Networks, pp.1–18.

[6] Chong, C. & Kumar, S., 2003. Sensor networks: evolution, opportunities, and challenges. Proceedings of the IEEE, 91(8).

[7] Ghosh, A. & Das, S., 2006. Coverage and connectivity issues in wireless sensor networks: A

survey. In R. Shorey et al., eds. Mobile, Wireless, and Sensor Networks: Technology, Applications, and Future Directions. John Wiley & Sons, Inc. 221, pp. 221–256.

[8] Ghosh, A. & Das, S.K., 2008. Coverage and connectivity issues in wireless sensor networks: A survey. Pervasive and Mobile Computing, 4(3), pp.303–334.

[9] Huang, C. & Tseng, Y., 2005. A survey of solutions to the coverage problems in wireless sensor networks. Journal of Internet Technology.

[10] Megerian, S. et al., 2005. Worst and best-case coverage in sensor networks. IEEE Transactions on Mobile Computing, 4(1), pp.84–92.

[11] Nittel, S., 2009. A survey of geosensor networks: advances in dynamic environmental monitoring. Sensors (Basel, Switzerland), 9(7), pp.5664–78.

[12] Prekop, P. & Burnett, M., 2003. Activities, context and ubiquitous computing. Special Issue on Ubiquitous Computing Computer Communications, 26(11), pp.1168–1176.

[13] Ryan, N., Pascoe, J. & Morse, D., 1998. Enhanced reality fieldwork: the context-aware archaeological assistant. Computer applications in archaeology.

[14] Schmohl, R. & Baumgarten, U., 2008. Context-aware computing: a survey preparing a generalized approach. Proc. of the Int. MultiConference of Engineers.

[15] Sharifzadeh, M. & Shahabi, C., 2004. Supporting spatial aggregation in sensor network databases. Proceedings of the 12th annual ACM international workshop on Geographic information systems - GIS '04, p.166.

[16] Soro, S. & Heinzelman, W.B., 2005. The coverage problem in video-based wireless sensor networks. In Broadband Networks, BroadNets. pp. 932 – 939.

[17] Szewczyk, B.R. et al., 2004. Habitat Monitoring with Sensor Networks. Communications of the ACM, 47(6), pp.34–40.

[18] Thai, M.T. et al., 2008. Coverage problems in wireless sensor networks: designs and analysis. International Journal of Sensor Networks, 3(3), p.191.

[19] Wang, G., Cao, G. & Porta, T. La, 2006. Movement-assisted sensor deployment. IEEE Transactions on Mobile Computing, 5(6), pp.640–652.

[20] Worboys, M. & Duckham, M., 2006. Monitoring qualitative spatiotemporal change for geosensor networks. International Journal of Geographical, 00(00), pp.1–28.

[21] Anon, 1999. 21 ideas for the 21st century. Business Week, pp.78–167.

[22] A. Bharathidasan and V. A. S. Ponduru. 2004. "Sensor networks: an overview," http://wwwcsif.cs.ucdavis.edu/∼bharathi/.

AUTHOR'S BIBLOGRAPHY

Megaram is currently pursing his Mtech in ECE from L.R Groups of institutions solan himachal pradesh, INDIA. His area if interest is wireless sensor network signal processing and smart antenna

Mahendra Tyagi is currently working as an Assistant Professor in the Department of Elecronics and Communication Engineering from L. R. Group of Intitutions, Solan, Himachal Pradesh, India. He has published his research in peer reviewed International Journals, and Conferences. His area of interest is Wireless Sensor Network, Signal Processing and Smart Antenna.

